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Airblast Damage to 30-kW, Skid-Mounted, Mobile Army Diesel Generator Sets

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A 30-kW, skid-mounted electric generator set of the tactical Army type was tested for structure-only damage under the impact of airblasts with peak pressures of 9.3 and 3.5 psi. Conclusions based on test results apply to three tactical models of 30-kW, skid-mounted, diesel generator sets available for Army field use. Test results indicate that generator sets will operate without interruption when exposed to an airblast with a peak pressure cont.

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of 3.5 psi. If the impacting peak pressure is 9.3 psi, the operation of the generator sets could possibly be interrupted because engine parts, generator terminals, and control circuits are damaged from major deformation of the access doors. Recommendations for low-cost hardening emphasize redesign of doors and other sheet-metal structures for survival under combined airblast and thermal pulse conditions.

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1. INTRODUCTION

1.1 Background

The class of 30-kW, skid-mounted, mobile electric generator sets of the Army-designated diesel tactical type is finding increased use in weapon and communication systems. Three models of such generator sets currently available for Army field use are considered in this report. One of these models is listed in the present Army inventory; production of the other two has been discontinued. All three models are similar in their electrical characteristics as well as in their structural features. None had ever been evaluated in terms of structural vulnerability to the impact of the blast wave resulting from the explosion of a tactical nuclear weapon.

Before formulating a program for full evaluation of the blast wave survivability of these generator sets, preliminary data were needed on the structure-only damage to be expected from their interaction with the blast wave.

To obtain such data quickly and cost effectively, advantage was taken of a major Air Force blast test in progress at Holloman Air Force Base (AFB), near Alamogordo, NM, in the summer of 1980. An already available 30-kW Army diesel generator set was exposed first to the impact of a simulated blast wave with a peak pressure of 9.3 psi* and then to another with a peak pressure of 3.5 psi. (It is desirable to expose a target to the low pressure first, but the generator set tests had to follow the Air Force program.) The planned peak pressure for the first test had been 7.3 psi; however, a source variation produced 9.3 psi.

The generator set tests were planned by a three-person group selected from the engineering staffs of the Ballistic Research Laboratory (BRL) and the Harry Diamond Laboratories (HDL). Both BRL and Holloman AFB technical personnel performed the tests.

1.2 Description of Generator Sets

Three models of the Army family of 30-kW, skid-mounted, mobile generator sets were considered for test:

- MEP-005A (Army inventory)
- SF-30 MD/CIED (non-Army inventory)
- Hol-Gar CE-301-AC/WK1 (non-Army inventory)

*1psi = 6.9 kPa.

All three models are diesel engine driven, can operate at continental United States and European voltages (110/220 V), and can provide 30 kW at 60-Hz operation or 25 kW at 50-Hz operation. The three models are similar in their other electrical characteristics as well as in their structural features.

1.2.1 Generator Set Model MEP-005A

Generator set model MEP-005A is the standard military design, Army inventory member of the 30-kW, diesel engine driven, utility type class. Table 1 lists its main characteristics; figure 1 shows front, side, and rear views of the generator set.

TABLE 1. CHARACTERISTICS OF MEP-005A GENERATOR SET

Parameter	Characteristic
Type	Tactical utility, Army inventory
Federal stock No.	6115-118-1240
Class	30 kW ac, portable, skid mounted, diesel engine
Volts	120/208, 240/416, 3 phase, 4 wire, wye connection
Amperes	102 at 120 V, 52 at 208 V
Power rating	30 kW at 60 Hz, 25 kW at 50 Hz
Length	80 in. (2.03 m)
Width	36 in. (0.9 m)
Height	55 in. (1.4 m)
Weight	2850 lb (1283 kg)
Technical manual	TM 5-6115-465-12

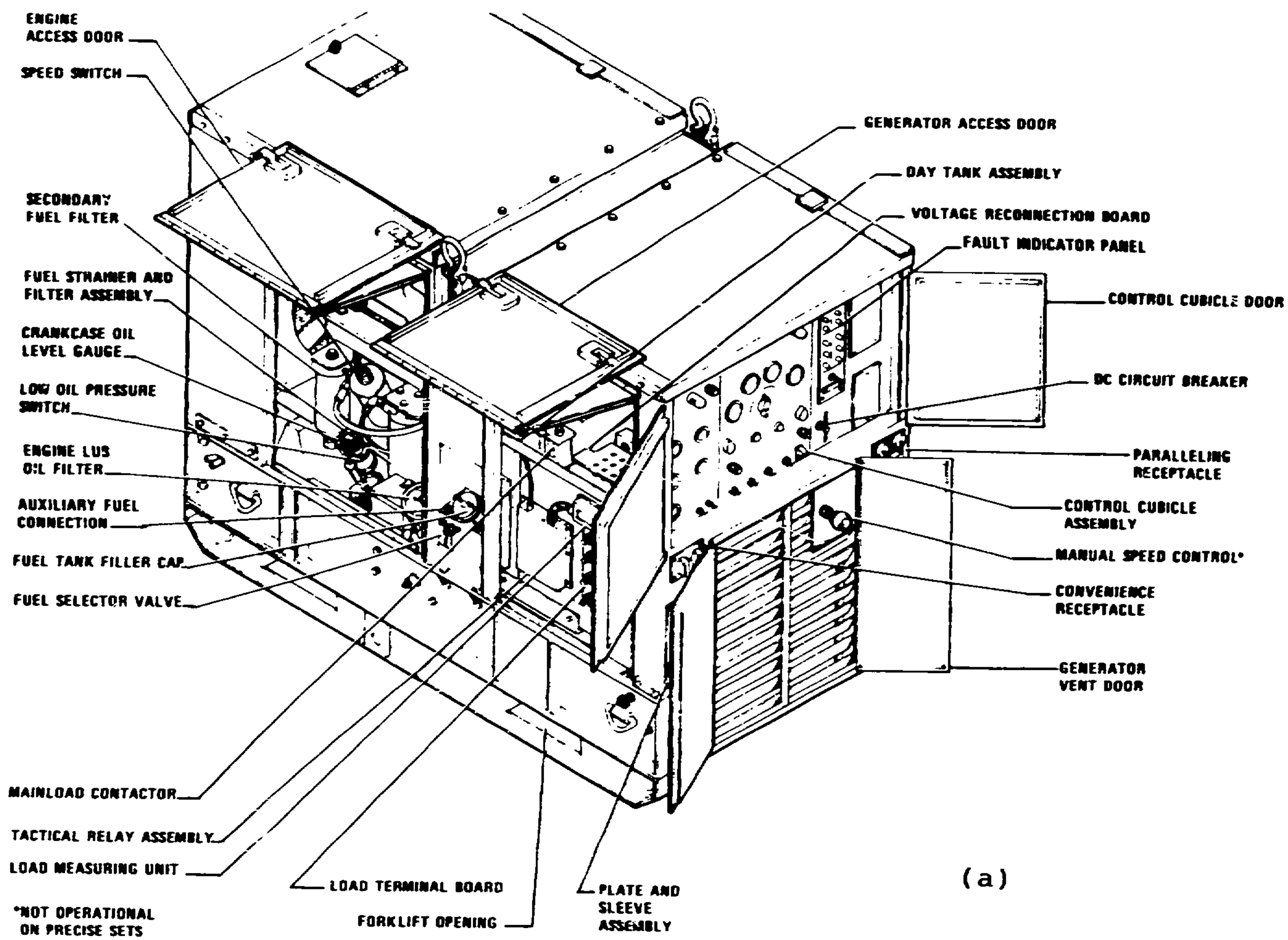


Figure 1. MEP-005A generator set: (a) left side and front (from Army Technical Manual TM 5-6115-465-12) (cont'd next page).

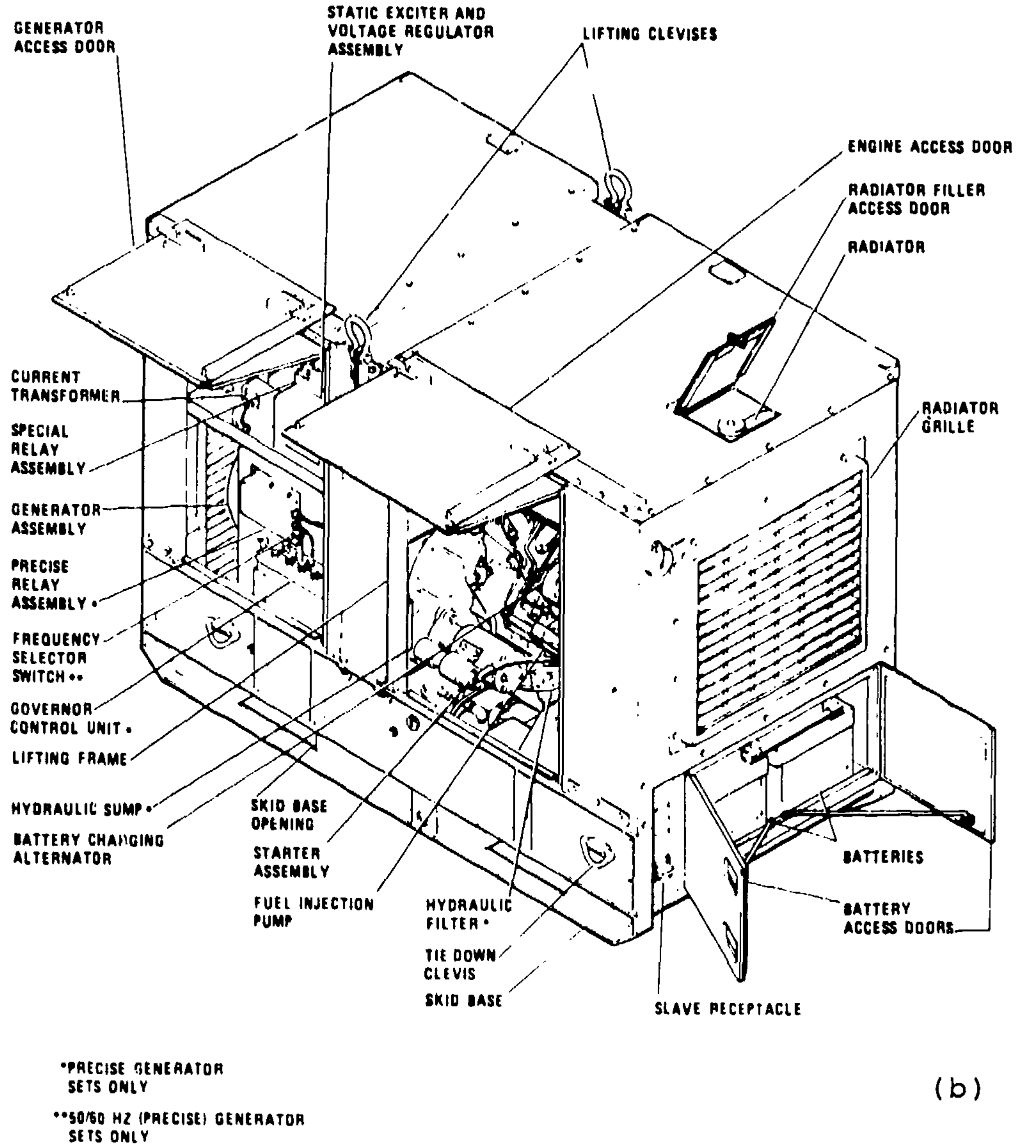


Figure 1 (cont'd). MEP-005A generator set: (b) right side and rear (from Army Technical Manual TM 5-6115-465-12).

1.2.2 Generator Set Model SF-30 MD/CIED

Generator set model SF-30 MD/CIED, no longer in production, is still widely used by the Army. Although of military design, it is not in Army inventory. Front, side, and rear views of the SF-30 MD/CIED are shown in figure 2; main characteristics are listed in table 2.

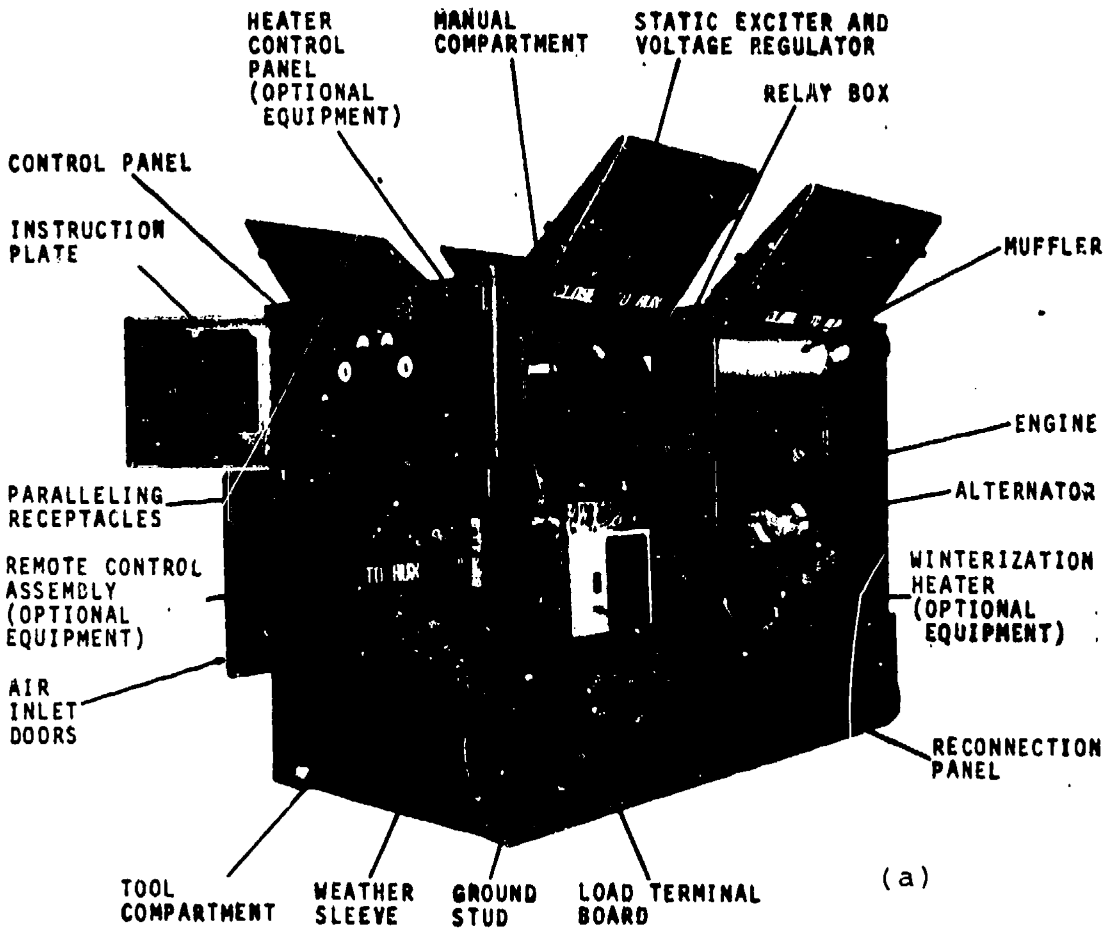


Figure 2. SF-30 MD/CIED generator set: (a) front and right side (from Army Technical Manual TM 5-6115-449-15) (cont'd next page).

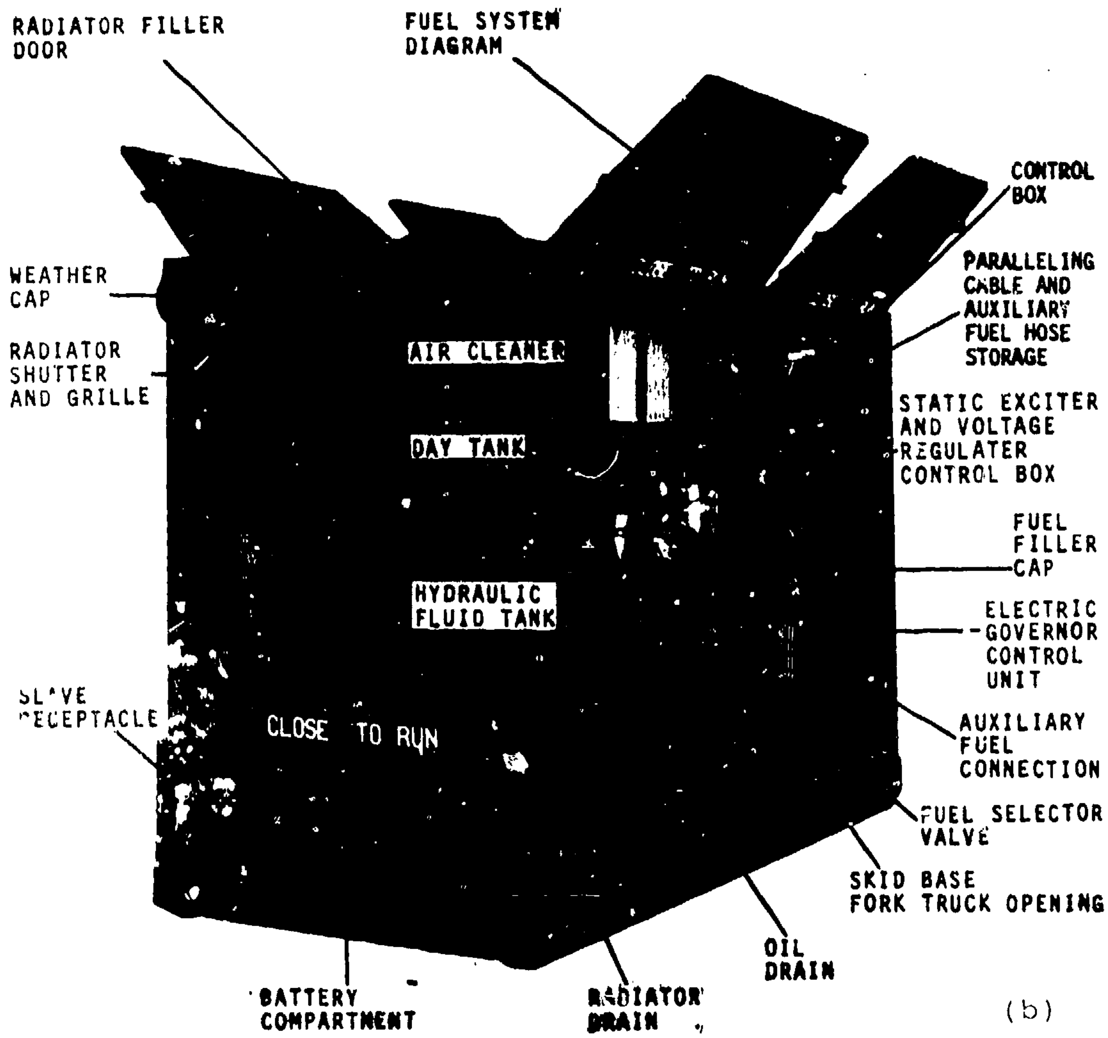


Figure 2 (cont'd). SF-30 MD/CIED generator set: (b) rear and left side (from Army Technical Manual TM 5-6115-449-15).

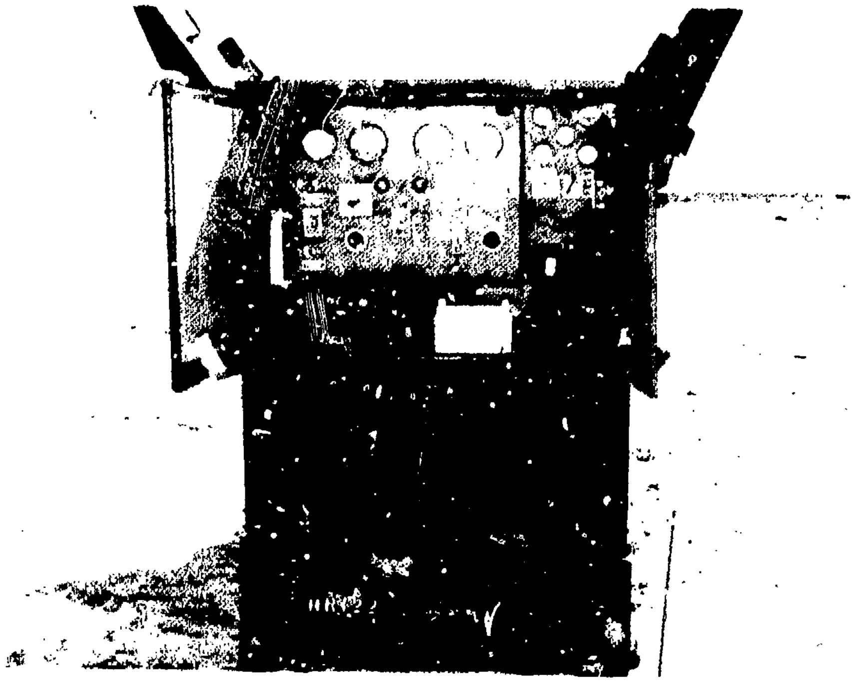
TABLE 2. CHARACTERISTICS OF SF-30 MD/CIED GENERATOR SET

Parameter	Characteristic
Type	Tactical utility, non-Army inventory, Westinghouse Electric Corp.
Federal stock No.	6115-935-5111
Class	30 kW ac, portable, skid mounted, diesel engine
Volts	120/208, 240/416, 3 phase, 4 wire, wye connection
Amperes	104 at 120 V, 52 at 208 V
Power rating	30 kW at 60 Hz, 25 kW at 50 Hz
Length	80 in. (2.03 m)
Width	36 in. (0.9 m)
Height	57 in. (1.45 m)
Weight	3400 lb (1530 kg)
Technical manual	TM 5-6115-449-15

1.2.3 Generator Set Hol-Gar Model CE-301-AC/WK1

Generator set Hol-Gar model CE-301-AC/WK1 is an earlier commercial version of the non-Army inventory, military design generator set model SF-30 MD/CIED (sect. 1.2.2). Figure 3 shows front, side, and rear views of this model; main characteristics are listed in table 3. Although production of this generator set has been discontinued for some time, this model is still used by the Department of Defense and was the model available for the Holloman AFB test.

(a)



(b)

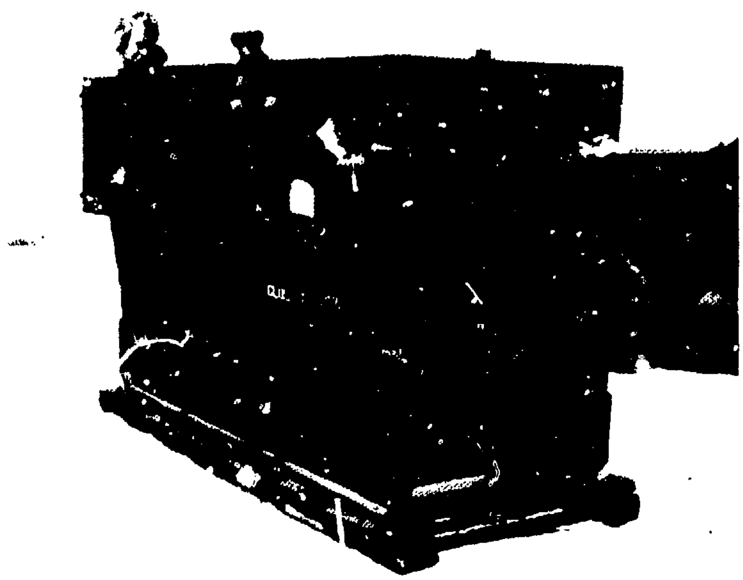


Figure 3. Hol-Gar model CE-301-AC/WK1 generator set before tests: (a) front and (b) right rear (cont'd next page).

(c)

(d)

Figure 3 (cont'd). Hol-Gar model CE-301-AC/WK1 generator set before tests: (c) right side, doors closed, and (d) right side, doors open.

TABLE 3. CHARACTERISTICS OF HOL-GAR CE-301-AC/WK1 GENERATOR SET

Parameter	Characteristic
Type	Tactical precision, non-Army inventory, General Motors Corp. diesel engine, Westinghouse Electric Corp. generator
Federal stock No.	6115-077-8600
Class	30 kW ac, portable, skid mounted, diesel engine
Volts	120/208, 240/416, 3 phase, 4 wire, wye connection
Amperes	104 at 120 V, 52 at 208 V
Power rating	30 kW at 60 Hz, 25 kW at 50 Hz
Length	81 in. (2.05 m)
Width	36 in. (0.9 m)
Height	55 in. (1.4 m)
Weight	3345 lb (1505 kg)
Technical manual	TM 5-6115-321-15

1.3 Blast Waveform Characteristics

The manner in which a blast wave interacts with a target has been well covered in the literature (for instance, Department of the Army Pamphlet 50-3).[1] Table 4 lists major parameters for two examples of blast waves generated at the ground surface by the detonation of a 20-kT nuclear weapon, that is, equivalent to 20,000 tons of TNT.[2]

[1] *The Effects of Nuclear Weapons, Department of the Army Pamphlet 50-3 (March 1973).*

[2] *Capability of Nuclear Weapons, Defense Nuclear Agency EM-1 (July 1972).*

TABLE 4. CHARACTERISTICS OF BLAST WAVE FROM 20-kT WEAPON AT GROUND SURFACE

Parameter	Characteristic	
	Test 1	Test 2
Peak overpressure	7.3 psi*	3.5 psi
Ground range	0.934 km	1.44 km
Time from detonation to blast wave arrival	0.14 s	2.8 s
Max flow velocity	103 m/s	43 m/s
Equiv wind speed	372 km/hr	155 km/hr
Positive phase duration	0.7 s	0.92 s

**Plan for test 1; 9.3 psi actually recorded. 1 psi = 6.9 kPa.*

The peak pressures of 7.3 and 3.5 psi are values often associated with high and low levels inside the range of moderate airblast damage to tactical systems.

Figure 4 depicts a typical nuclear airblast waveform and illustrates the criteria for determining positive phase. For structure-only tests of tactical components such as generator sets, the crushing effect of the positive phase is the prime damage mechanism.

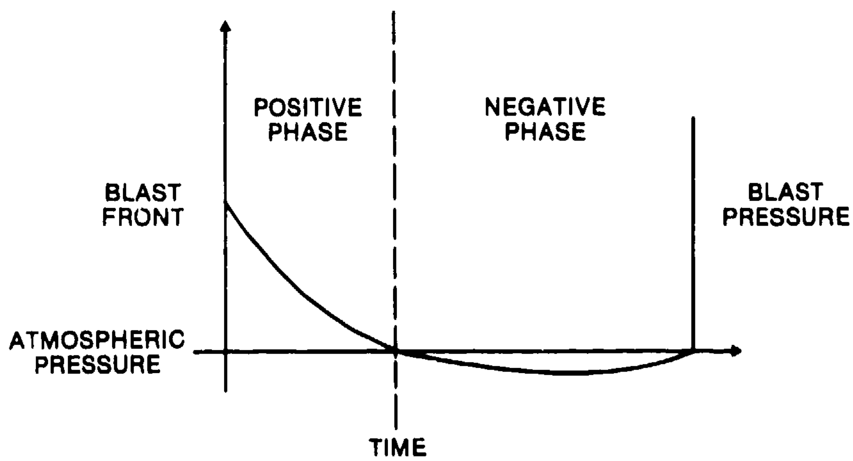


Figure 4. Variation of pressure as blast wave passes generator set (from Joseph J. Halpin et al, Nuclear Weapon Effects on Army Tactical Systems, Vol. I, HDL-TR-1882-I, April 1979).

The type of high-explosive charge used in the generator set tests consisted of a mixture of ammonium nitrate and fuel oil (ANFO). Figure 5, a cutaway view of a typical ANFO charge, depicts a stack of ANFO bags with a seven-section detonation booster at its center.

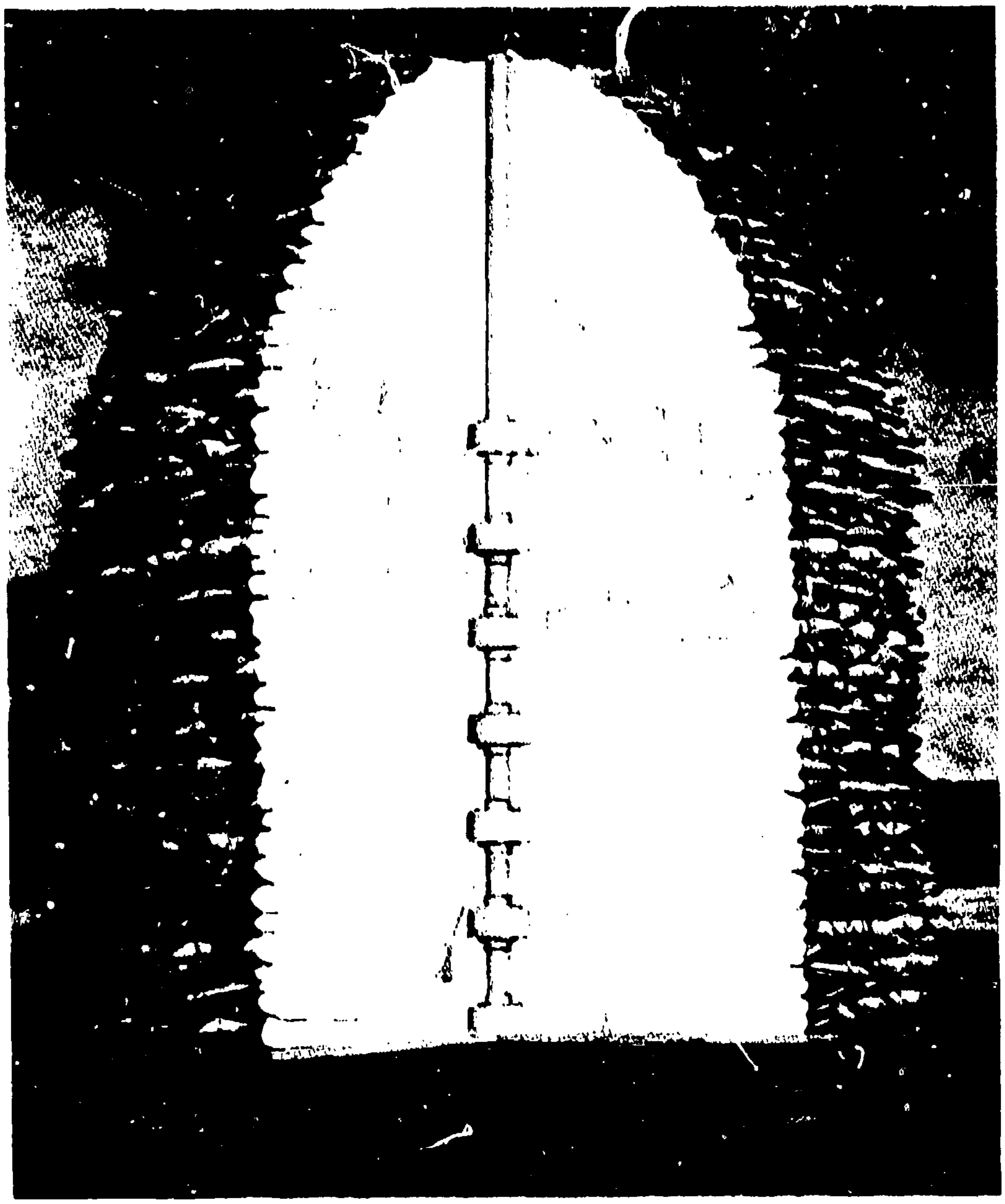


Figure 5. Typical stack for ammonium nitrate and fuel oil, cutaway view.

2. DESCRIPTION OF TESTS

Objective.--The objective was to provide, at low cost and limited range, experimental support to determine how a nuclear blast affects a class of tactical Army electric power generator sets. Specific goals were these:

- To determine the effects of a blast wave on the generator set structure, parts, and operation (Peak pressures of 7.3 and 3.5 psi were specified.)

- To formulate any need for low-cost, structural hardening fixes against threats at the 7.3- and 3.5-psi peak levels

- To determine any need for combined blast and thermal tests at a 7.3-psi peak level or higher

Location.--The tests were conducted at Holloman AFB (fig. 6).

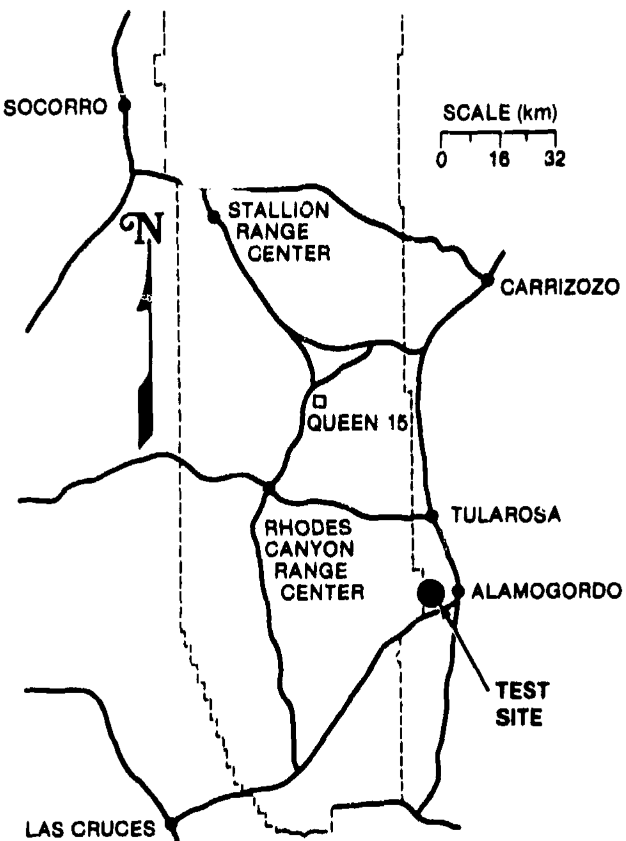


Figure 6. Site for tests with Hol-Gar model CE-301-AC/WK1 generator set.

Organization.--A three-person group from BRL and HDL conducted the generator set tests. Overall operational and organizational management for the tests was the responsibility of the project manager of the major Air Force event into which the generator set tests were incorporated.

Blast wave source.--A high-explosive charge, consisting of 240 bags of ANFO, was stacked and ignited with a single Pentolite booster as shown in figure 7.

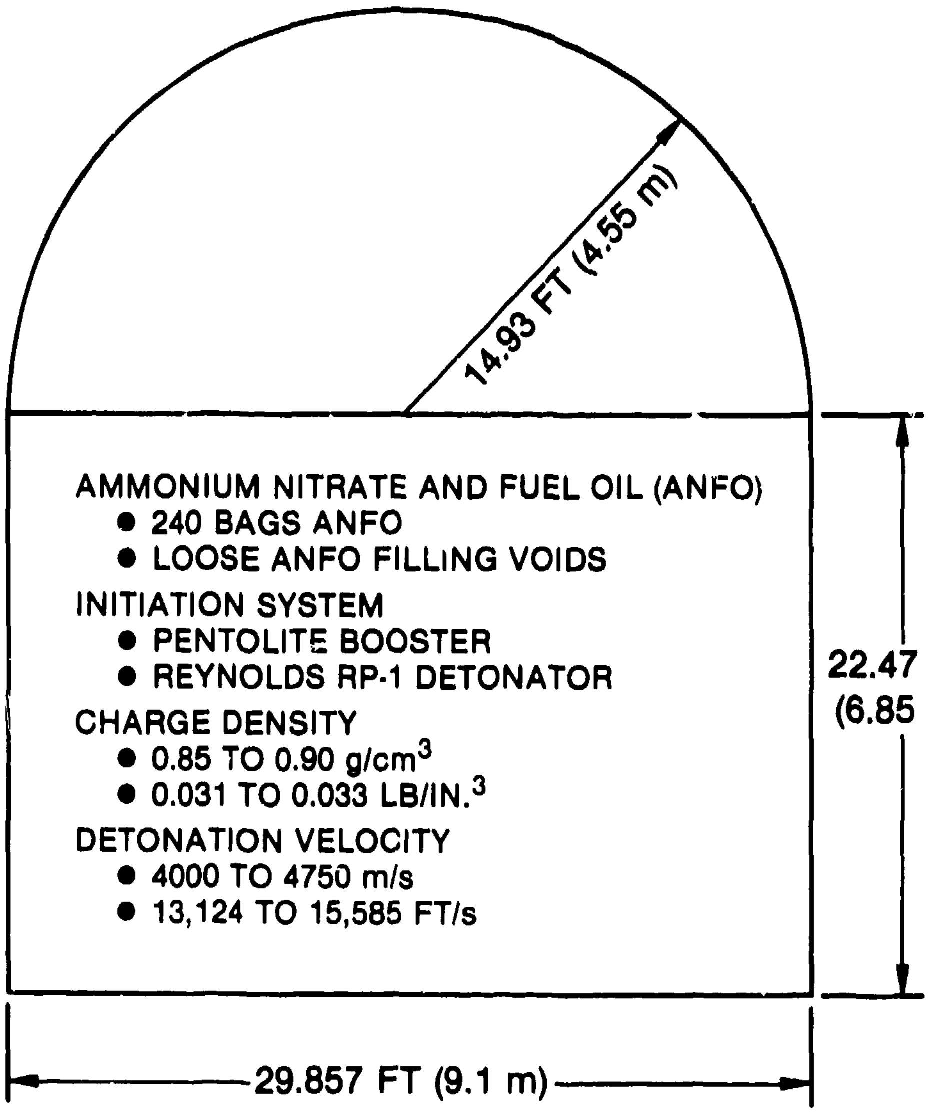


Figure 7. Sketch of blast wave source.

Test target.--The unit under test was a single, non-Army inventory, CE-301-AC/WK1 generator set. This model is similar to models MEP-005A and SF-30 MD/CIED.

Test 1.--Referring to figure 8, the generator set was exposed broadside to an airblast environment predicted along the 7.3-psi peak isopressure line. A sensor gage was placed along the same peak pressure line. Figure 9 depicts the recorded test waveform. The actual pressure recorded was 9.3 psi, a not uncommon deviation in ANFO tests.

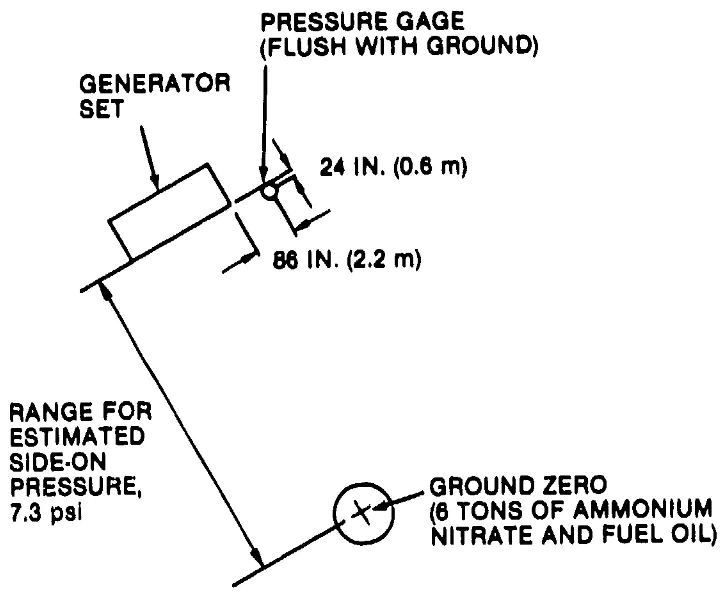


Figure 8. Sketch of airblast test setup for Hol-Gar model CE-301-AC/WK1 generator set.

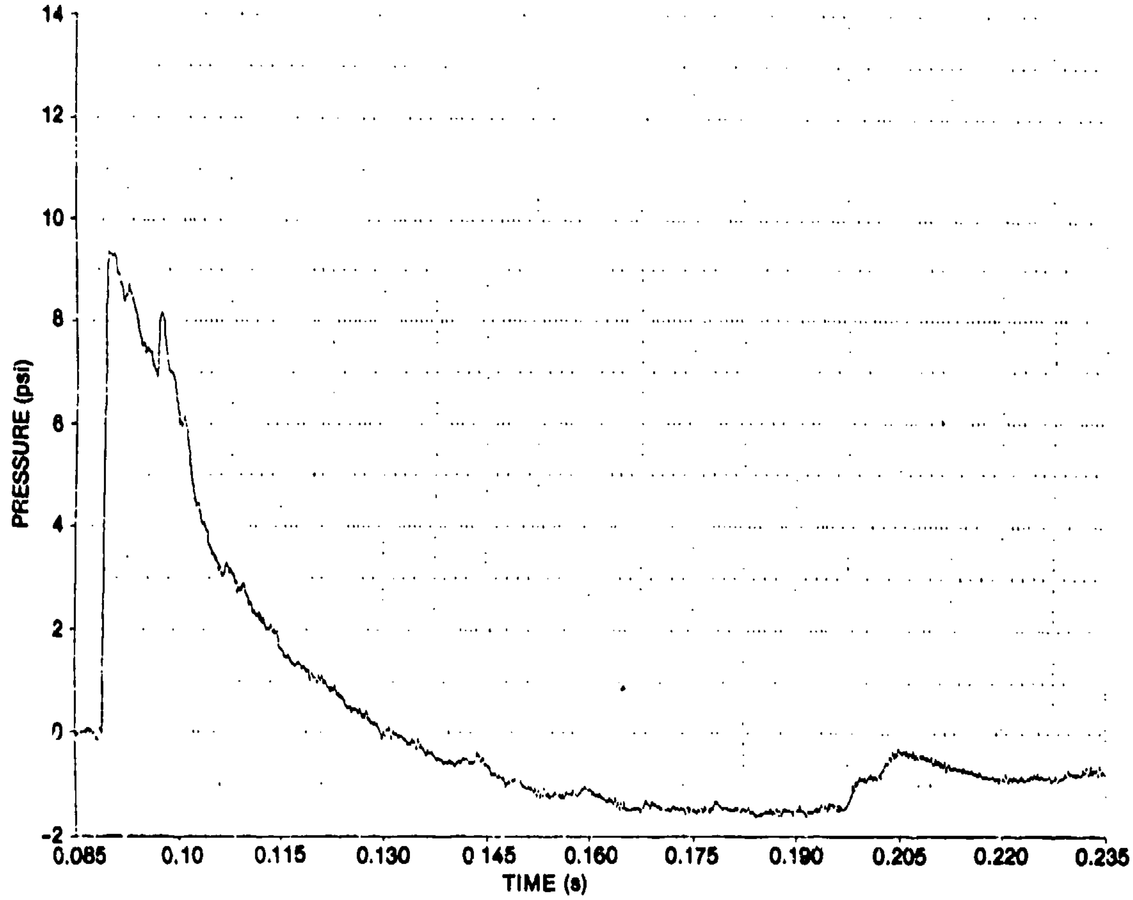


Figure 9. Waveform record, test 1 on Hol-Gar model CE-301-AC/WK1 generator set.

Test 2.--The second test was performed in the same manner as the first, but along the 3.5-psi isopressure line. A record of the test airblast is shown in figure 10. Lacking a second test unit and spare parts, the generator used in the first test was used in the second test. The upwind side doors damaged in the first test were replaced with undamaged downwind side doors. Two board panels were installed in place of the original doors on the downwind side.

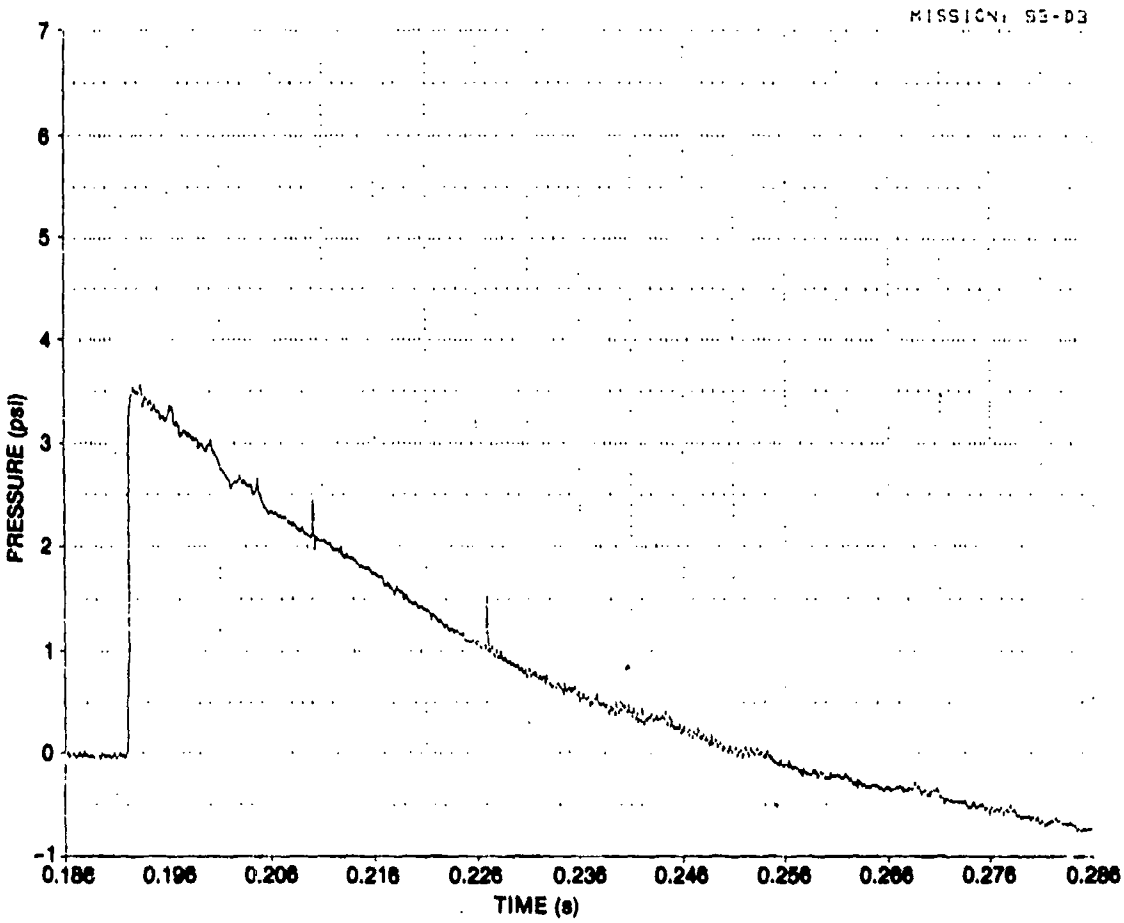


Figure 10. Waveform record, test 2 on Hol-Gar model CE-301-AC/WK1 generator set.

3. TEST RESULTS

3.1 Test 1

The broadside impact of the 9.3-psi peak blast wave caused extensive buckling of the upwind side doors and of the front and rear doors. The deformed side doors in turn impacted on vulnerable parts of the diesel engine and on the terminals of the generator power and control circuits. After this test, damaged engine parts and terminals were repaired in the field in about 2 hr. For some other waveform or angle of impact, the component damage may be somewhat different. Specifics of the damage are summarized in tables 5 and 6. Actual records are shown in appendix A.

TABLE 5. DAMAGE TO STRUCTURE OF HOL-GAR CE-301-AC/WK1 GENERATOR SET IN TEST 1

Part	Record sheet
Upwind side doors severely buckled and front panel doors severely damaged	A-1
Upwind side doors severely buckled	A-2
Air access door and door check bar damaged, hinge bracket rivet sheared off	A-3
Downwind side doors only slightly damaged	A-4
Body top bin slightly buckled near center lift ring and rivet sheared off	A-5

TABLE 6. DAMAGE TO ENGINE AND GENERATOR OF HOL-GAR CE-301-AC/WK1 GENERATOR SET IN TEST 1

Part	Record sheet
Air filter (oil type) case perforated by deformed door	A-6
Oil sump filler tube bent by impact of deformed door	A-7
Base of upper rear power wire terminal cracked by impact of deformed door	A-8

3.2 Test 2

After the damaged upwind side doors were removed and replaced with the downwind side doors, the generator set used in test 1 was used in test 2. The photograph in record sheet A-9 (app A) shows the upwind side of the generator set under test after the 3.5-psi peak blast impact. The only damage to the generator set was minor deformation (buckling) of the upwind side doors. No damage to the parts in the engine or in the generator systems was recorded after test 2.

4. CONCLUSIONS

The conclusions are derived from an engineering assessment of the results from the CE-3C1-AC/WK1 tests. The conclusions apply also to Army design models MEP-005A and SF-30 MD/CIED because the strong structural similarity among the three models insures that their blast responses will be the same. The three models belong to the Army family of 30-kW, skid-mounted, mobile, diesel generator sets.

4.1 Damage from 9.3-psi Peak Blast Wave

For a peak blast pressure wave of 9.3 psi, the main frame will not be damaged, but the main body will be damaged slightly, and upwind doors might be damaged seriously or irreparably. Parts of the diesel engine section, as well as terminals and circuits in the generator section, are expected to be damaged by the impact of deformed doors; consequent interruption of operation also can be expected. Thus, at the 9.3-psi peak level, direct support maintenance will be required.

4.2 Damage from 3.5-psi Peak Blast Wave

For a peak blast wave of 3.5 psi, the engine and the generator access doors might buckle slightly, but not sufficiently to damage the engine and generator parts and cause operation failure. Front and rear doors also might buckle, particularly if they are directly exposed to the blast front. Thus, only minor maintenance is foreseen.

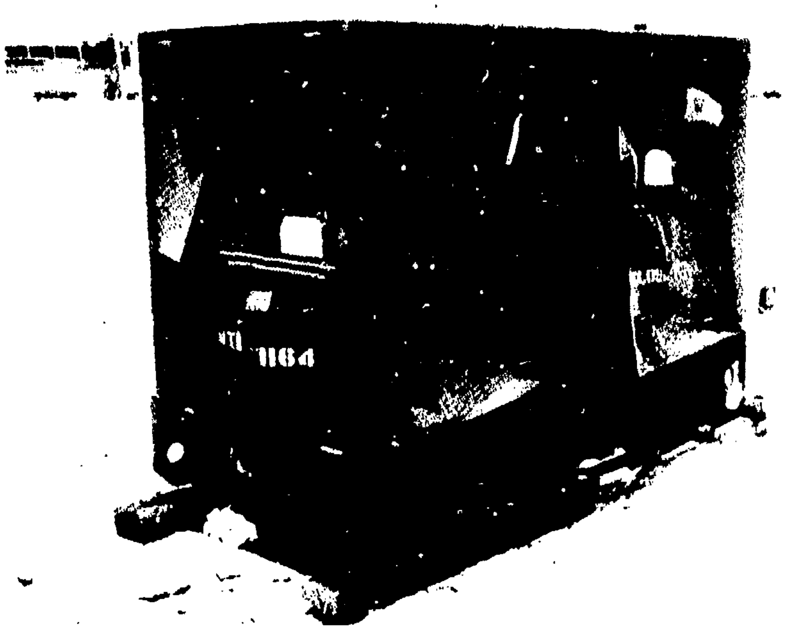
5. RECOMMENDATIONS

The cost-effective hardening approach recommended to the materiel developer is the redesign of the structural and sheet metal portions of the generator sets. The redesign should not only alleviate the damage recorded in this airblast testing, but also consider the effects of a thermal radiation pulse preceding the blast wave. Strength characteristics of the sheet metal could certainly be reduced by the thermal pulse. Typical fluences to be considered are 80 to 110 cal/cm^2.

APPENDIX A.--PHOTOGRAPHIC RECORDS FOR AIRBLAST TESTS OF 30-kW GENERATOR SET

This appendix contains the photographic records taken at the Holloman Air Force Base, NM, tests on a single tactical 30-kW, skid-mounted, electric generator set, Hol-Gar model CE-301-AC/WK1. This model is electrically and structurally similar to military design Army models MEP-005A (Army inventory) and SF-30 MD/CIED (non-Army inventory).

APPENDIX A



Record sheet No. A-1

Date 20 August 1981

Peak pressure (psi) 9.3

Test waveform Figure 9

Test leader G. Teel

Observers K. Warner, R. Peterson

Damage Upwind side doors severely buckled and front panel doors severely damaged

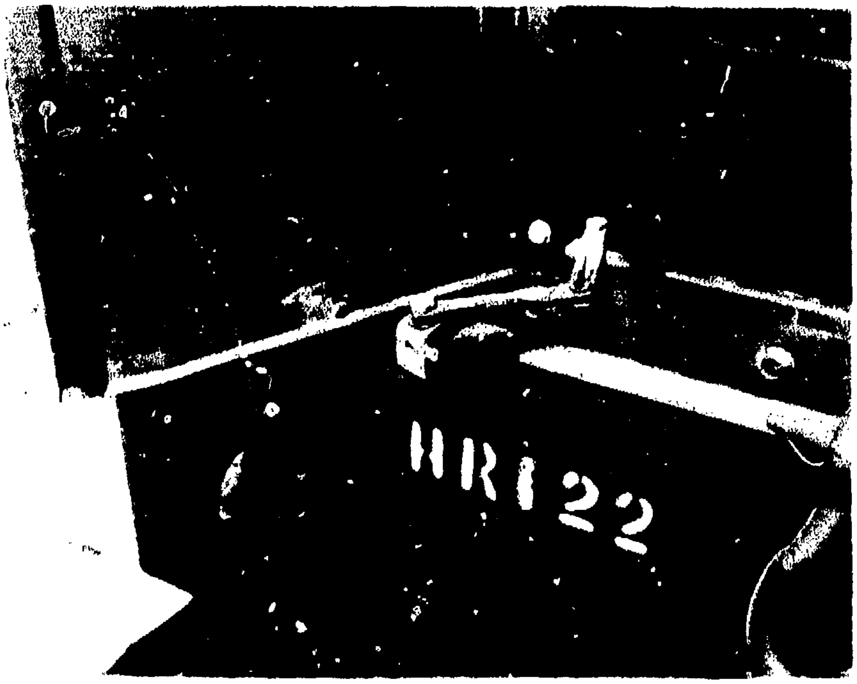
Record sheet No. A-2 | Date 20 August 1981

Peak pressure (psi) 9.3 | Test waveform Figure 9

Test leader G. Teel | Observers K. Warner, R. Peterson

Damage Upwind side doors severely buckled

APPENDIX A



Record sheet No. A-3

Date 20 August 1981

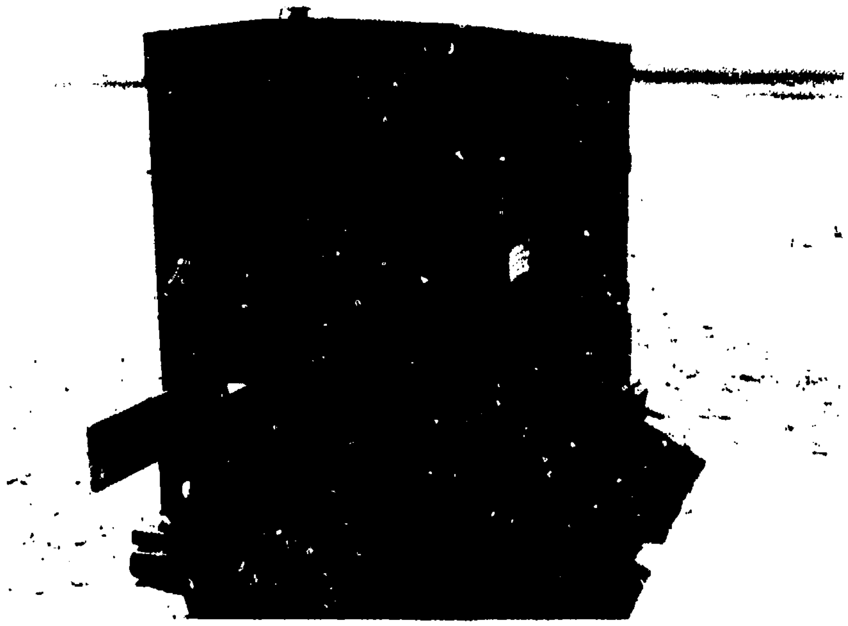
Peak pressure (psi) 9.3

Test waveform Figure 9

Test leader G. Teel

Observers K. Warner, R. Peterson

Damage Air access door and adjustable door check bar damaged, hinge bracket rivet sheared off



Record sheet No. A-4

Date 20 August 1981

Peak pressure (psi) 9.3

Test waveform Figure 9

Test leader G. Teel

Observers K. Warner, R. Peterson

Damage Downwind side doors only slightly damaged

APPENDIX A

Record sheet No. A-5

Date 20 August 1981

Peak pressure (psi) 9.3

Test waveform Figure 9

Test leader G Teel

Observers K. Warner, R. Peterson

Damage Body top bin slightly buckled near center lift ring and rivet sheared off

Record sheet No. A-6

Date 20 August 1981

Peak pressure (psi) 9.3

Test waveform Figure 9

Test leader G. Teel

Observers K. Warner, R. Peterson

Damage Air filter (oil type) perforated by deformed door

APPENDIX A

Record sheet No. A-7

Date 20 August 1981

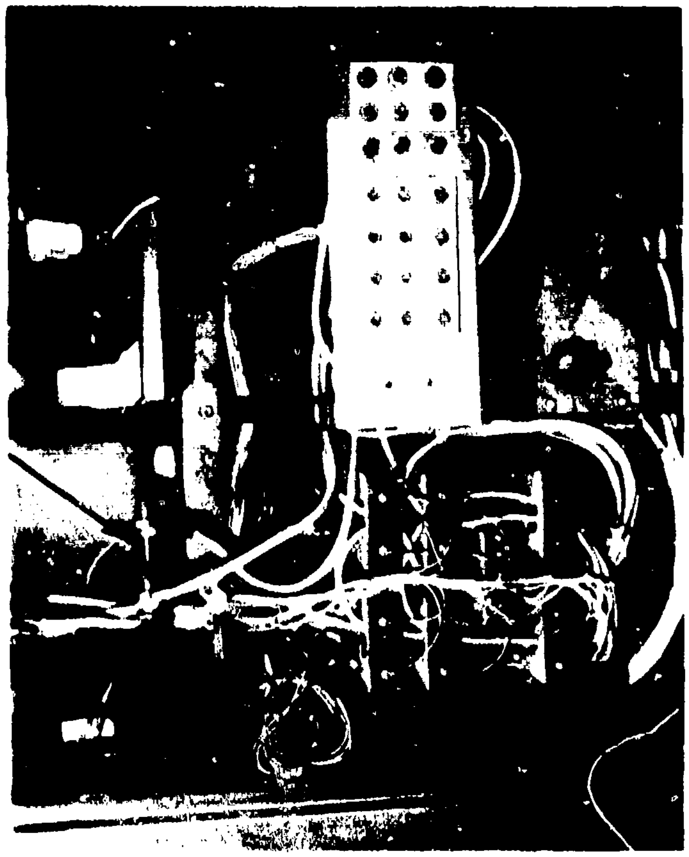
Peak pressure (psi) 9.3

Test waveform Figure 9

Test leader G. Teel

Observers K. Warner, R. Peterson

Damage Oil sump filler tube (arrow) bent by impact of deformed door



Record sheet No. A-8

Date 20 August 1981

Peak pressure (psi) 9.3

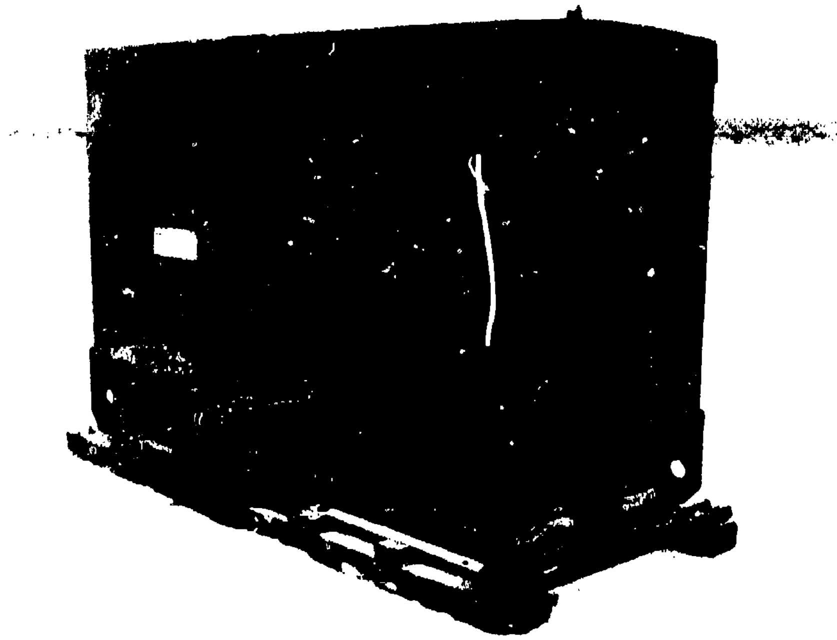
Test waveform Figure 9

Test leader G. Teel

Observers K. Warner, R. Peterson

Damage Base of upper rear power wire terminal (arrow) cracked by impact of deformed door

APPENDIX A



Record sheet No. A-9

Date 13 September 1981

Peak pressure (psi) 3.5

Test waveform Figure 10

Test leader G. Teel

Observers R. Peterson

Damage Upwind side doors slightly damaged by low-level (3.5-psi) peak pressure

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